633 2

Arizona State University

Reinforcement Variables in the Control of Unit Textual Responses

By

Arthur W. Staats, Judson R. Finley, Karl A. Minke

and Montrose Wolf

Technical Report No. 23 for Contract Nonr-2794 (02)

(Psychological Processes in Language Communication)

between

Arizona State University and Office of Naval Research

March 1963

Reinforcement Variables in the Control of Unit Textual Responses[1]

Arthur W. Staats, Judson R. Finley, Karl A. Minke,

and Montrose Wolf[2]

Arizona State University

The first author and his associates have undertaken a systematic experimental analysis of the acquisition of textual behavior (see Staats and Staats, 1962). In the first experiment of this project (Staats, Staats, Schutz, and Wolf, 1962) a preliminary experimental procedure was devised and the effect of extrinsic reinforcers (edibles, tokens, and trinkets) on the maintenance of reading behavior was explored. The results indicated the potential productiveness of the application of operant conditioning principles and procedures to the study of this type of behavior.

Additional areas of development were suggested by the above results. For example, a continuous record of reading responses was desirable in order to provide a more sensitive measurement of the effect of experimental variables. Further, a homogeneous program for the presentation of textual stimulus units was needed so that the program itself did not impose strong characteristics on the record, thus obscuring the effects of other independent variables. Finally, it was important to devise a system of reinforcement for use with pre-school subjects which would maintain good working behavior for the long period involved in reading acquisition.

Work was begun on the development of an experimental procedure, recording apparatus, and a system of reinforcement with which to more precisely study the acquisition of textual behavior. Using these developments a study was conducted in which three 4-year-old children were run in 20-minute training sessions. The children continued the training until E suspended the experiment and in two cases the training extended for 40 sessions with the behavior remaining in good strength to the end (Staats, Minke, Finley, Wolf, and Brooks, in press).

The results suggested that the procedure and recording technique could produce sensitive records of the conditioning of textual responses and that the reinforcement system was capable of maintaining work and attentional behaviors over long periods of time. The present study investigates the value of the materials, apparatus, and general procedure for producing reliable results relating independent variables to the dependent variable of reading acquisition, i.e., the effect upon reading rate of the manipulation of various reinforcement schedules, using multiple schedule techniques. In addition to validating the extension of certain behavior principles to this complex type of human learning, the experiment tests variables and procedures important to the further study of reading (and other types of child learning) and to the construction of an effective reading program.

---

[1]This study represents part of a research project applying conditioning principles to the study of language learning supported by the Office of Naval Research under Contract Nonr-2794 (02). The authors wish to thank Dr. Roy Doyle and Caryl Steere of the Arizona State University Campus Laboratory School for their assistance in providing subjects.

[2]Now at the University of Washington.

Method

Subjects

Four 4-year-old children (3 boys, 1 girl), who would be entering kindergarten at the Arizona State University Campus Laboratory School the following fall semester (1962), were volunteered for participation in the experiment by their parents. The female S failed to exhibit the behaviors requisite to the experimental procedure following the pretraining period and was replaced by a male S from the same population. The children were transported by E to and from the Language Learning Laboratory.

Materials and Apparatus

The reading characters consisted of letters and letter combinations in conjunction with special identifying marks. These characters were introduced into the program one at a time according to a complex circuiting formula, and no character was ever completely dropped from the program.

The program was presented to S on 5 x 8 white index cards, each card constituting a frame. On each card the appropriate character was typed in lower case primary letters, and below it in randomly assigned positions appeared one matching and two non-matching characters. Thus, each card was designed such that discrimination training could be carried out.

Materials for the pretraining procedures were as follows: (1) a list comprising the various vowels and consonants in the program was constructed as an echoic task, vowels in this list presented singly and consonants presented in simple words; and (2) thirty matching-to-sample discrimination cards utilizing simple line drawings of familiar objects were constructed in a manner similar to the discrimination cards for the reading material.

A vertical panel containing a small plexiglass window and three similar windows centered below it was mounted on a table in front of S; a slight push on a window activated a microswitch. The printed portions of a program card could be viewed through the windows. Beneath each of the lower three windows was a corresponding button, and a press of the button below the correct window activated a marble dispensing device. A small red light was located in the center of the panel below the buttons and a doorbell-type pushbutton was on the table in front of S. A light on E's side of the panel illuminated the stimulus card. A light was mounted above the center panel, another on the wall above the displayed toys, and the room's overhead lighting system was wired to the programming equipment. A group of relays were employed to control the sequencing of the reading response chain. Any response by S which occurred out of the proper sequence resulted in the automatic sounding of a buzzer. A portion of this system is included in the accompanying diagram of the experimental chamber (Fig. 1).

Insert Fig. 1 about here

A marble dispenser, which when activated caused a marble to roll down a tube into a small box lying at its base, was located on the table in front of S, slightly to his right.

To the left of S was a large cabinet housing a Universal Feeder which could dispense a plastic trinket,[3] an edible (small candy, pretzel sticks, etc.), or a

3 The trinkets employed were small plastic rings, stars, balls, tools, shoes, utensils, cups, tops, coins, etc., distributed by the Paul A. Price Co., Inc., 55 Leonard Street, New York 13, N. Y.

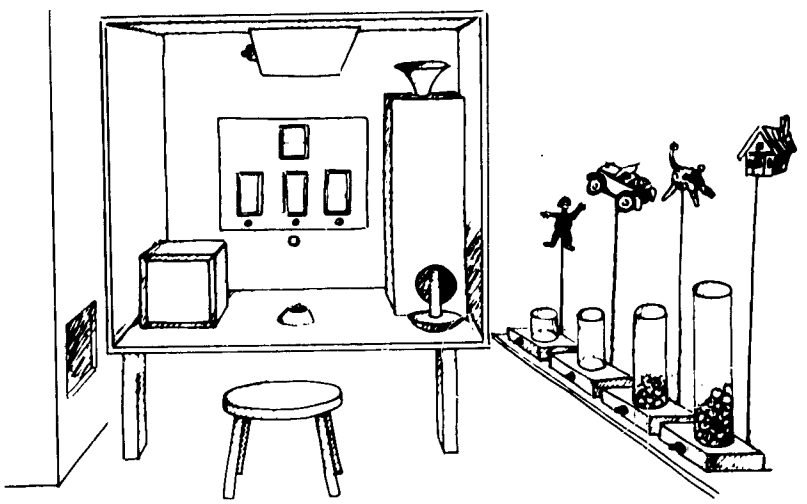


Fig. 1.--The laboratory apparatus for the experimental study of reading behavior. The intercom speaker at the child's left allows vocal behaviors to be monitored from outside the experimental chamber (from Staats, Minke, Finley, Wolf, and Brooks, in press).

penny into an open bin adjacent to S. The feeder was activated by a marble dropping into a funnel located at the top of the marble dispenser. When a marble was placed in this funnel, a bell inside the dispenser rang and the multicolored plastic front of the dispenser was briefly illuminated.

S could also place a marble in one of four clear plexiglass tubes which were located in a row on a low shelf at his extreme right. Each tube held a different number of marbles: 10, 35, 80, or 150. Above each tube a toy was displayed which S had previously selected from the "toy cafeteria." Beneath each tube was located a small colored bulb which could be lighted by E when the tube was full. This system is also depicted in Fig. 1.

The toy cafeteria consisted of a room containing four display tables which were isolated from one another so that S could select toys from any table without the other displays being visible. Four samples of toys were available, the average cost of the toys in each sample being $.10, $.35, $.80, and $1.50. Thus, for each plexiglass tube in the experimental chamber there was a corresponding sample table in the toy cafeteria from which the child could select toys for display over the tubes. The $.10 sample consisted of 15 toys, and the other samples each consisted of 10 toys. These toys were obtained from local toy stores,[4] and a heterogeneous population of toys was provided for each price value.

The automatic contingencies and recording were handled by standard operant conditioning apparatus. A Gerbrands cumulative recorder was used to record S's responses, the delivery of a toy, and the operation of the Universal Feeder. The paper speed for the recorder was 15 centimeters per hour, and each response double-stepped the recording pen.

Occasionally the automatic equipment would malfunction during a daily session, causing a brief interruption of the procedure in order to make repairs. At such times S was removed from the experimental chamber and taken into a playroom containing a hobby-horse.

Procedure

The pretraining procedures were designed to establish the response sequences appropriate to the reading task. During pretraining continuous reinforcement was employed. E initially presented the echoic task, in which S was required to make a matching vocal response to the vowel or word spoken by E. The purpose of the echoic task was two-fold: to assure that each S had a sufficient repertoire of vocal responses to echo rather precisely the verbal stimuli to be presented in the experiment, and to bring echoic responding under the control of E.

Two types of pretraining discrimination tasks were then presented. Discrimination Task A used the picture cards to establish the following chain: (1) S presses the button mounted on the table in front of him and a card is presented; (2) E names the picture in the top window, at which time S pushes the top window, turning on the red light, and echoes E; (3) S pushes the matching lower window, turning out the red light, and repeats the verbal response; (4) S pushes the button below the matching lower window, delivering a reinforcer.

In Discrimination Task B, S was instructed to "anticipate," if possible, i.e., to name the picture in the upper window before E provided the verbal stimulus. On

[4]Included among the $.10 items were a number of miniature products such as boxes of tissue or aluminum foil, picnic coolers, soft drink bottles, model rockets, straw games, etc., which were provided by Merry Manufacturing Company, 531 N. Wayne Avenue, Cincinatti 15, Ohio.

each trial E waited 10 seconds after presenting the picture card before giving the prompt. Correct anticipation responses by S were immediately reinforced without requiring S to perform the chain. The buzzer was sounded after incorrect anticipations; E then gave the correct verbal response and S was required to go through the appropriate discrimination chain. Finally, if S did not anticipate at all, E gave the correct name at the end of the 10 seconds, and S was required to complete the entire chain. Thus, there were three different contingencies in terms of the immediacy of reinforcement upon S's possible anticipation behaviors.

The entire pretraining procedure was conducted under the illumination afforded by the light mounted above the panel plus the wall light. This was done so that the pretraining procedures would be conducted under light conditions intermediate to those employed as controlling stimuli under the multiple schedule procedure.

Immediately following the completion of Discrimination Task B the light mounted on the wall was turned off and the first card of the actual reading program was presented. Except for the schedule of reinforcement and the light conditions, the procedures used in the reading task were identical to those employed in Discrimination Task B. However, two Ss displayed some breakdown in the response chain when the reading materials were introduced and occasional prompting of the appropriate chain behaviors was maintained for them for the first few sessions.

During the entire experiment, including pretraining, E's verbal responses to S were minimal; once the appropriate behaviors were established E's only verbal behavior consisted of the presentation of stimulus materials or occasional instructions. All attempts by S to interact with E were subjected to extinction, and E was particularly careful to avoid such behaviors as smiling, nodding, looking over the panel, etc. in response to any such attempts at interaction on the part of S.

The effects of four reinforcement schedules were investigated--variable ratio (from VR 2 to VR 6), variable interval (VI 2'), continuous reinforcement (CRF), and extinction (EXT). Each child was run under a two-component multiple schedule, each S receiving two of the experimental conditions. The schedule combinations presented were as follows: CRF-EXT, CRF-VR, CRF-VI, and VR-VI. It was initially decided to begin the variable ratio at a VR 6, but as the experiment progressed, it became obvious for both Ss receiving VR components that the ratio was too high. Therefore, it was dropped to VR 2 and raised gradually only after the response rate became somewhat stable under the VR 2 condition.

The change of condition under the multiple schedule was effected reinforcer-contingent for CRF and VR components and time-contingent for VI and EXT components. The CRF component was in effect for 15 reinforcers, and the VR component for 5 reinforcers; the VI schedule was in effect for 10 minutes, and the extinction component was 5 minutes in duration.

For the 3 Ss presented multiple schedules containing a CRF component, this condition always commenced a session and was correlated with the "no-light" condition (room illumination from the light mounted over the panel only). The other component for an S was then presented under the "light" condition (illumination from both the panel light and the room's overhead lighting system). For the S presented the VR-VI schedule, the VR component was always presented first under the "no-light" condition. Each day the experiment was terminated after 20 minutes, regardless of which component was in effect and regardless of the length of time that the component had been in effect. Each S was slated to run for 30 sessions.

Correct responses (i.e., either correct anticipations or terminal button-pressing responses of the reading chain) were reinforced with a marble according to the appropriate reinforcement schedule. S could place this marble in the marble dispenser to

activate the Universal Feeder or in any one of the four plastic tubes. Thus, the delivery of back-up reinforcers (i.e., toys, edibles, and trinkets) was self-adjusting, and S could obtain an immediate back-up reinforcer of low monetary value or could use his marble to work toward more remote but higher-valued reinforcers.

When S placed his marble in the dispenser, he was given a clear plastic bag in which to place the objects obtained from the Universal Feeder. He was allowed to consume the edibles during the experimental session or he could take them home.

When one of the plastic tubes had been filled, E signaled that S has earned the toy associated with that tube by momentarily lighting the small bulb at the tube's base and by ringing the bell and flashing the light in the marble dispenser. The cumulative recorder was immediately stopped, the toy given to the child, and the marble tube was emptied. A new toy was then mounted above the tube, and the recorder started. The delivery of a back-up reinforcer was performed with minimal interaction between S and E. Just prior to each day's experiment S was taken to the toy cafeteria to select enough toys to replace those earned the previous day.

Results

CRF-EXT Subject

In the daily session record for the CRF-EXT S the actual reading program was introduced at point A in Session 3 (see Fig. 2). Records prior to this point represent performance on the various pretraining tasks. Point B notes the inadvertant reinforcement of a response in the first extinction component. Sessions 4-30 commenced with CRF conditions which then alternated with the EXT condition. At point C the first six responses under EXT were accidently reinforced, S was removed from the chamber during repairs, the recorder reset, then appropriate EXT conditions were presented to S. Point D indicates that in Session 18 each EXT component was only of 3'20" duration.

Insert Fig. 2 about here

Fig. 2 also shows the operation of the back-up reinforcer system for each session The event marker on the line below each curve notes the occurrance of a back-up reinforcer: 1 indicates that a 10¢ toy was presented in exchange for 10 marbles, o marks the presentation of a 35¢ toy for 35 marbles, and unlettered event marks indicate that S deposited a marble for some item from the Universal Feeder. The record thus shows that S worked primarily for trinkets and edibles and for low value back-up toys which could be obtained with the marbles received during a single CRF component. In fact, S was often observed to place the first 10 marbles received under the CRF condition into the 10¢ tube and to use the remaining marbles for Universal Feeder items.

The record shows that the response rate under the two components became somewhat differentiated in Session 6, with responding during EXT generally decreasing across sessions through Session 26. From Sessions 27-30 the EXT rate accelerated. An over-all comparison of the effect of the differing contingencies is obtained when the records for the reading sessions are pieced together by components. Fig. 3 indicates that the EXT rate slightly exceeded the CRF rate until A, at which point the curves crossed and separated at an ever increasing pace, a classic picture of an S^D-S^Δ discrimination.

Insert Fig. 3 about here

A number of observations of S's work and attentional behaviors were also obtained. For example, S rapidly acquired the requisite behaviors of Discrimination

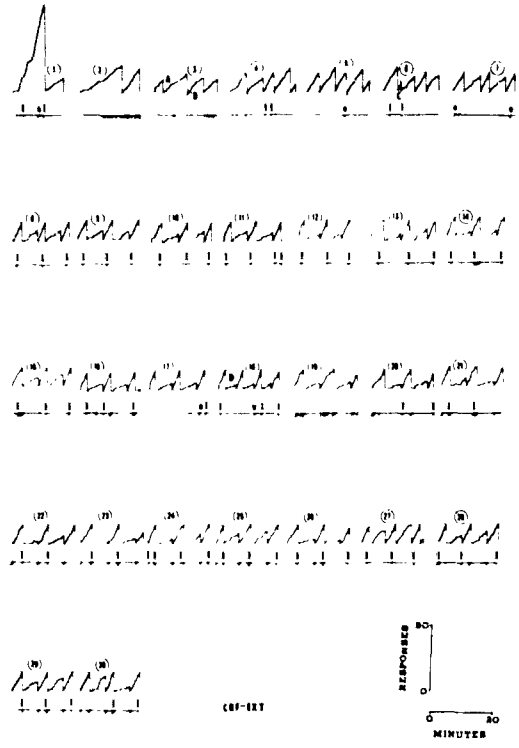
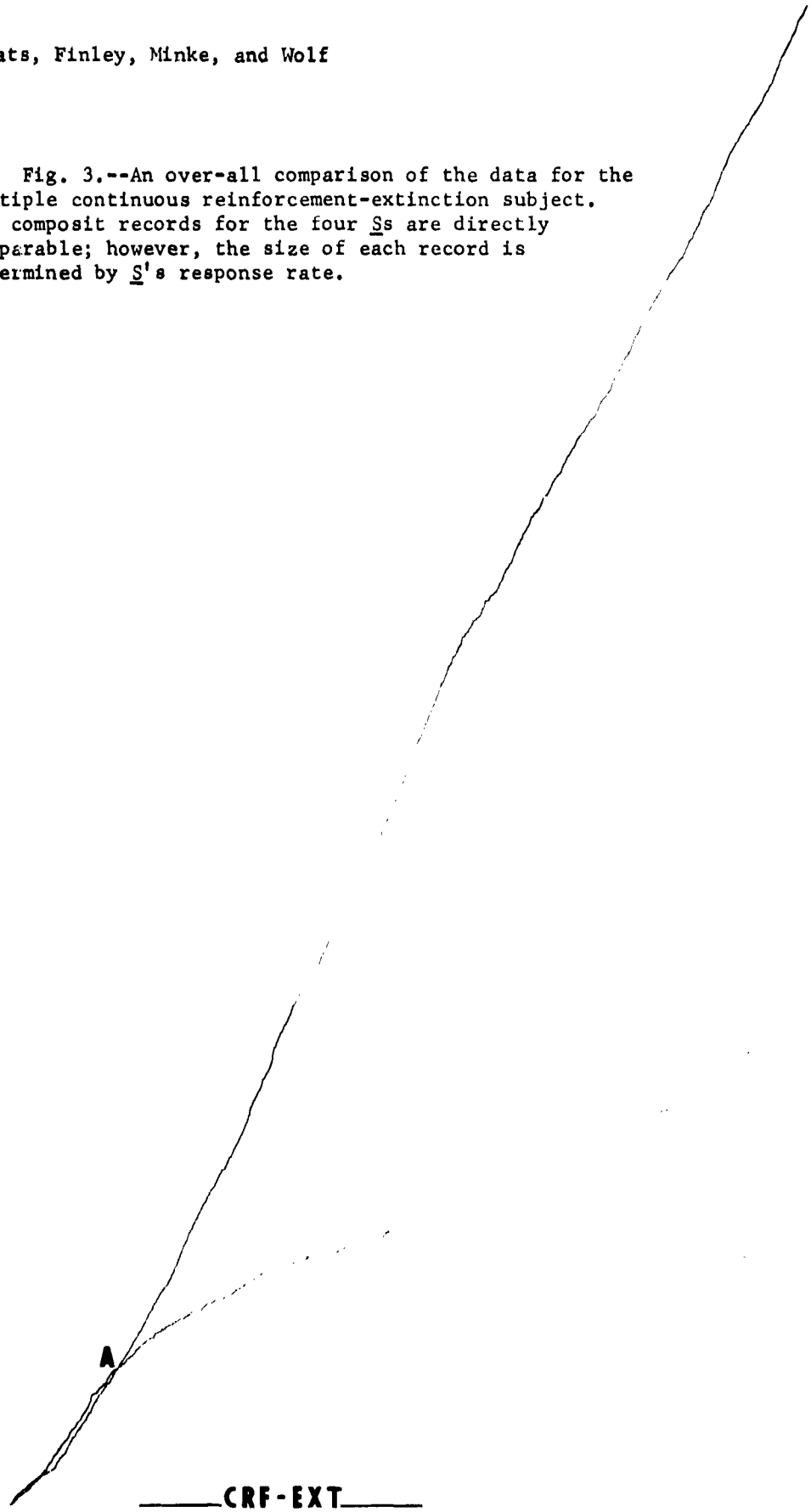


Fig. 2.--The daily session record for the subject presented a multiple continuous reinforcement-extinction schedule.

Fig. 3.--An over-all comparison of the data for the multiple continuous reinforcement-extinction subject. The composit records for the four Ss are directly comparable; however, the size of each record is determined by S's response rate.



Tasks A and B, and moved into the reading program with no "breakdown" in the complex response sequence. After the first non-reinforced response of the initial EXT component S stood up and leaned around to E to point out that no marble had been delivered. S behaved in this manner repeatedly across the 5-minute interval, engaging in a number of emotional behaviors. This occurred again during the first EXT component of Session 4, and the response rate under this component was somewhat suppressed. However, at the beginning of the second EXT component of the session, S said, "I know, when the light comes on I don't get any marbles." At this point verbalizations concerning the failure of marble delivery and emotional responding ceased, and the response rate again paralleled that under CRF conditions. Thus, the verbal behavior had become appropriate to the reinforcing contingencies in Session 4 (S was "aware"), although no permanent decrement in response rate occurred until Session 6. These results indicate that the variable of awareness does not necessarily bring about behavior appropriate to the experimental contingencies as proposed by a number of investigators, e.g., Dulany (1962). Verplanck (1962) reports a series of experiments in which awareness and motor behavior were independently manipulated. The present experiment further demonstrates an instance of the independence of these two types of behavior, in that awareness during the EXT component actually resulted in an increase in response rate by eliminating the emotional behaviors which were produced.

Behaviors other than the reading response rate were also found to be correlated with the component stimuli. Initially, S would "hoard" marbles during CRF, depositing them in the tubes when conditions changed to EXT. S would also echo incorrectly during EXT components, although many correct anticipations occurred in CRF periods. Both of these behaviors disappeared after a few sessions.

Beginning with Session 15 S, near the end of an EXT component, would complete the reading response sequence with the exception of the terminal button press responses, this response would then occur as soon as CRF conditions prevailed. During the experiment S often spent his time during EXT manipulating his acquired toys and trinkets, or playing on the floor.

S was presented with a total of 1608 reading trials in the experiment. Anticipation data for Session 23 is not available; however, data recorded for 1565 reading responses shows that 92.20% were anticipated, and 29.65% were anticipated correctly.

CRF-VR Subject

Fig. 4 is the daily session record for the CRF-VR subject. At point A the reading program was introduced under CRF conditions. Sessions 3 through 30 commenced with CRF conditions which then alternated with VR components. Point B marks where the recorder was inadvertently left off after an equipment repair, and approximately 3-minutes of responding under the two conditions are missing from the record.

Insert Fig. 4 about here

S was placed on VR 6 in Session 2 and remained on this VR schedule until point C, at which time the ratio was dropped to VR 2. A VR 3 schedule was initiated at point D, a VR 4 at point E, and VR 5 at F. An equipment failure at point G resulted in the first VR component of the session being presented under continuous reinforcement. Marbles delivered during VR responding are indicated on the curves by slash marks.

Fig. 4 also records S's use of the reinforcer system for each session. The marking convention for delivery of a back-up reinforcer is the same as for the previous S, with the addition that v indicates the exchange of 80 marbles for an 80¢

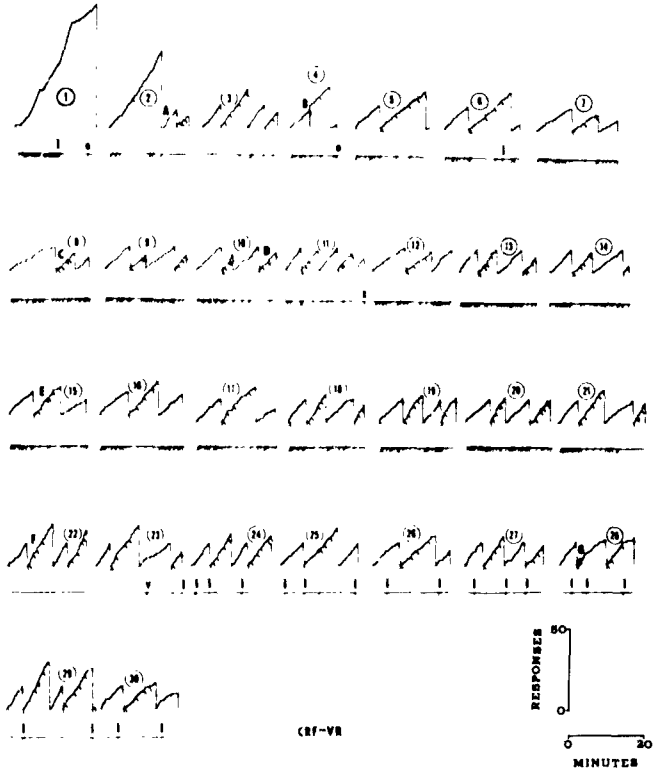


Fig. 4.--The daily session record for the subject presented a multiple continuous-variable ratio reinforcement schedule.

toy, and z notes the delivery of a 150-marble toy. In early sessions S worked primarily for items from the Universal Feeder. His over-all response rate increased as he began working towards the 150-marble toy; its delivery at the close of Session 11 was followed by a marked reduction in responding in Session 12. This same effect of the delivery of a "large" back-up reinforcer may be seen in Session 23 where receipt of the 80-marble toy in the CRF component produced a decline in rate followed by a scalloping effect. S employed the Universal Feeder system extensively until Session 21 (during which time it malfunctioned twice), then shifted primarily to 10¢ toys.

The figure indicates that rate differences between the two components did not become apparent until after reduction of the VR schedule in Session 8. The composite curves in Fig. 5 show that in early reading program sessions the two rates were almost identical, the VR rate beginning slightly below the CRF rate and crossing only at point A; from this point on the accelerated rate appropriate to a VR schedule was obtained. CRF component responding remained relatively stable while VR component responding continued to increase across sessions.

Insert Fig. 5 about here

S acquired the chaining behaviors rapidly in pretraining phases, and continued to respond smoothly when the reading materials were introduced. By Session 19 S's rate during VR components had risen to such an extent that E was having difficulty in manually administering the reading program promptly in response to S's initiation of each trial. In fact, the VR rate may well have been higher if the procedure had been automated to a greater extent. In Session 29 the highest number of responses emitted by any S ever run in this procedure was obtained--92 reading trials in the 20-minute session--and as can be seen, the acceleration occurred in the VR components

S's in-trial chaining performance was smooth throughout the experiment; however during the 10-second delay periods when S failed to anticipate, a "sing-song" type of verbal sequence which had developed in early sessions would often occur. S would look around the room, then respond quickly when E provided the trial's verbal stimulus.

S was presented a total of 1519 reading trials during the experiment. Correct anticipation figures for Session 26 were not recorded; however, an analysis shows that of 1476 reading trials, 46.14% were anticipated, and 43.36% anticipated correctly.

CRF-VI Subject

The daily session record for the CRF-VI S is depicted in Fig. 6. Point A marks the commencement of the reading program. For Sessions 4 through 30 CRF conditions began each session, then alternated with a VI 2' schedule which lasted 10 minutes. Between points B and C a special contingency was applied to S's chaining behaviors, and in Session 20 multiple schedule conditions were resumed. At point D the VI component lasted only 5 minutes. Marbles delivered during VI responding are indicated on the record by a slash mark.

Insert Fig. 6 about here

The marking system for back-up reinforcer delivery is the same as for previous Ss. During the initial session S deposited all his marbles for Universal Feeder items; inadvertently, this was not depicted on the session record (see Fig. 6). In subsequent sessions S used only the tube system. The record shows that S worked from Session 2 until the latter part of Session 7 without a single back-up reinforcer, and then until Session 10 before receiving another. A decrement in response rate followed the earning of each toy. The value of the back-up toys earned systematically decreased as the sessions progressed; i.e., S first worked for the "highest" value toy, then for lesser value toys, and finally only for 10¢ toys. In Session 29 S

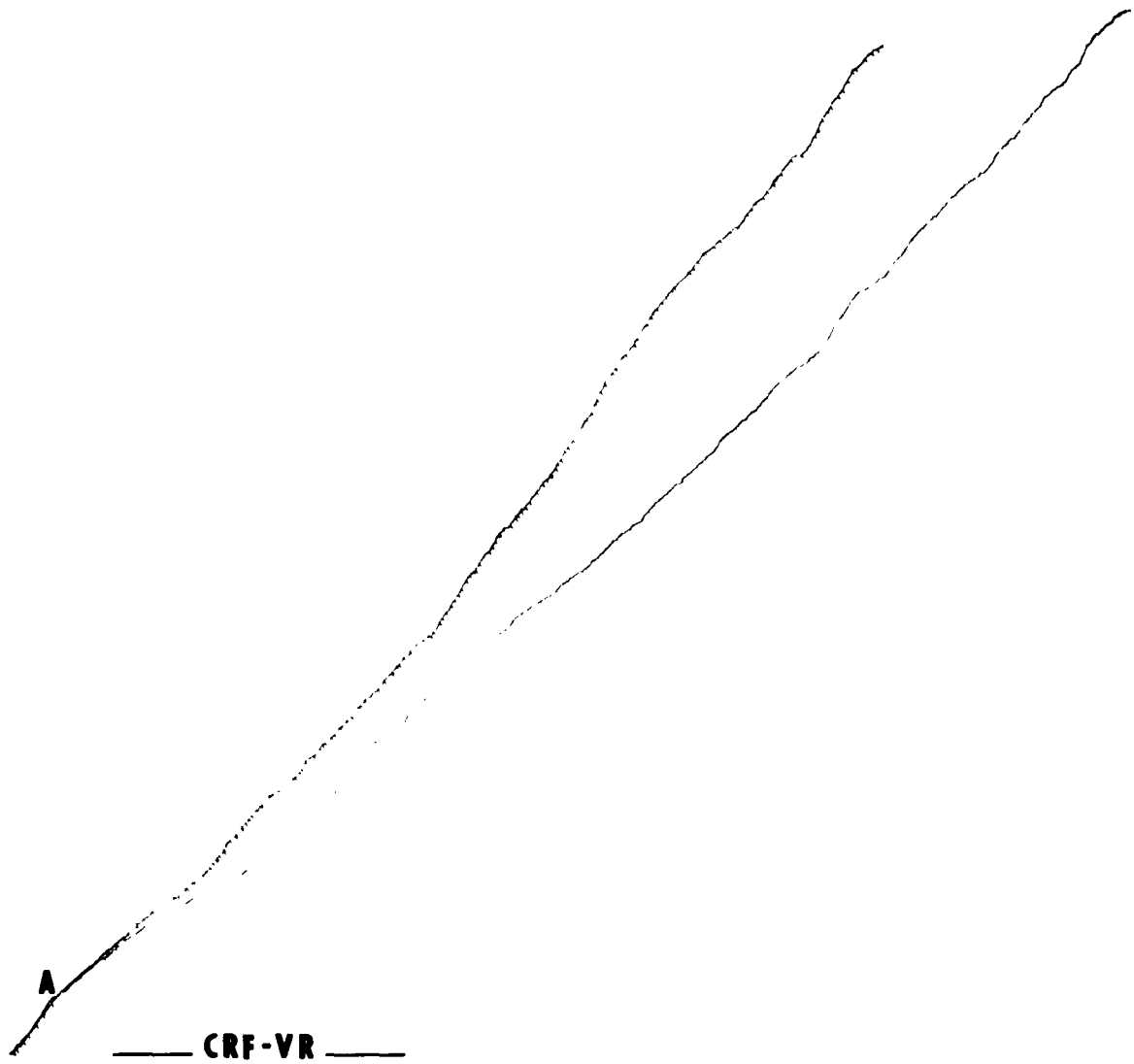


Fig. 5.--An over-all comparison of the data for the multiple continuous-variable ratio reinforcement subject.

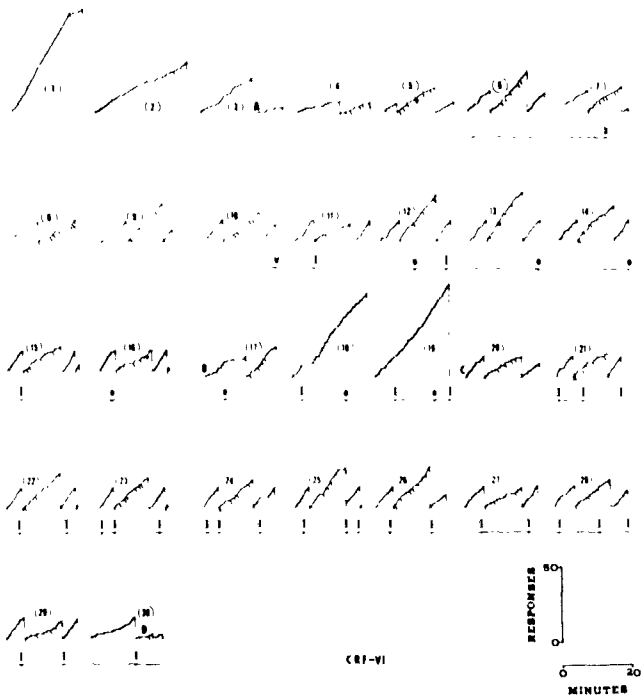


Fig. 6.--The daily session record for the subject presented a multiple continuous-variable interval reinforcement schedule.

took marbles remaining in the 80¢ tube and heaped them into the 10¢ tube. When E did not deliver the back-up reinforcer for this method of filling the tube, S returned the marbles to the 80¢ tube and began to fill the 10¢ tube appropriately.

Fig. 7 indicates most clearly the rate differences that developed between the two schedules. Responding during VI components essentially remained at a stable rate throughout--which was initially higher than under CRF. The rate under CRF accelerated after the first quarter of the curve at which point the CRF rate was higher than the VI. The rates were retained in this relationship and at point A the cumulative records crossed with the CRF retaining the lead thereafter. Data for Sessions 17-19 do not appear on this record.

Insert Fig. 7 about here

Introducing the reading program produced long pauses in the response chain and extensive prompting was required. In Session 4 three reading cards were dropped from the series under CRF conditions because a predetermined limit of five chaining errors was reached. Only eight responses were recorded under CRF conditions for Sessions 4 and 5 due to equipment malfunction.

By Session 12 the chaining behaviors were beginning to deteriorate, particularly under VI conditions. In Sessions 13-15 a "pecking" behavior developed in which S would begin the chain by pressing the top window, then quickly press back and forth from this window to the lower-center, lower-left, then lower-right windows respectively, until one of these responses resulted in a correct sequences as indicated by the absence of the buzzer. In order to eliminate this "pecking" behavior, which began to occur frequently in both CRF and VI components, a special contingency was introduced in Session 17. Whenever S began the "pecking" sequence, resulting in the buzzer sounding, E removed the stimulus card; the card was re-presented as soon as S ceased playing with the apparatus, and the trial continued.

For Session 17 the contingency was applied under both CRF and VI components. For the following two sessions it was applied only under CRF conditions so as to insure that reinforcement would always be available for the occurrence of a correct chain or a correct anticipation. By Session 19 the "pecking" behavior occurred on only 7 trials, so the multiple schedule was resumed in the following session with the special contingency being applied as needed. In Session 26 an equipment failure resulted in no marbles being delivered under the second CRF component.

Characteristic pausing behaviors under VI responding consisted of turning from the panel and staring at the reinforcer display. These behaviors occasionally occurred immediately upon the onset of the VI component stimulus. In addition, S would sometimes press the windows so as to activate the buzzer, then sound the buzzer for long periods of time.

A total of 1234 reading trials were presented during the experiment, 22.93% of which were anticipated correctly. Data for anticipatory behavior for Sessions 17-30 is not comparable to that of Sessions 3-16 due to the special contingency initiated in Session 17. However, in Sessions 3-16, 581 reading trials occurred, 75.39% of which were anticipated, and 24.96% were anticipated correctly.

VR-VI Subject

For the VR-VI S the reading program proper was begun at point B (see Fig. 8). At point A multiple errors occurred on a pretraining trial, and, since appropriate prompting procedures had not been developed at this time, the trial was not completed within this session. Point B marks the beginning of the reading task under VR 6 conditions, as well as a procedural error which resulted in multiple stepping of the

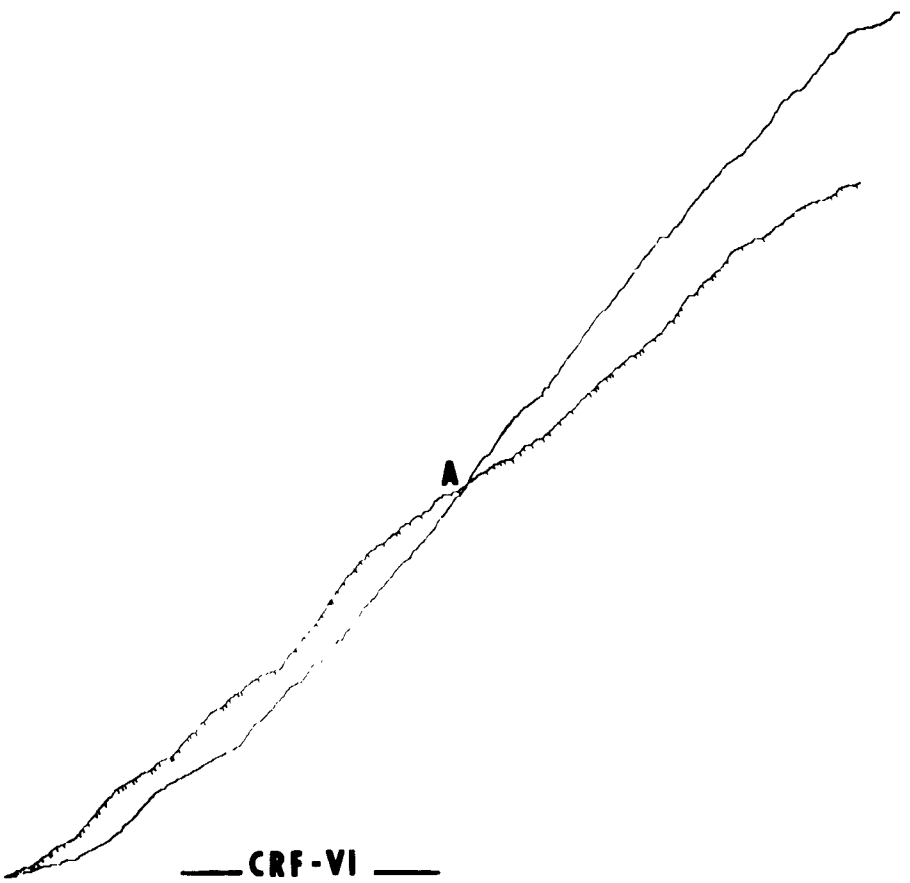


Fig. 7.--An over-all comparison of the data for the multiple continuous-variable interval reinforcement subject.

response pen. At point C both session components were VI. Sessions 6-30 commenced with a VR component which then alternated with a VI component. Point D notes that in the VI component of Session 6 no marbles were delivered; this occurred again for VI conditions in the following session. In addition, reinforcers delivered in VR conditions for both of these sessions were not marked on the record. The ratio schedule was reduced to VR 2 at point E, raised to VR 3 for the second VR component of the following session, then reduced to VR 2 again until Session 25 where it was raised to VR 3, remaining there for the balance of the experiment. Marble delivery for both schedules is indicated by slash marks on the curves.

Insert Fig. 8 about here

Fig. 8 shows that S received relatively few reinforcers for reading program sessions during the experiment--an average of 11.40 per session (excluding Sessions 6 and 7), varying from only 1 in Session 4 to 16 in several later sessions. S worked initially for an 80¢ toy, the receipt of which in Session 9 produced a decline in response rate, and he then obtained a number of 35¢ toys. In Session 23 S shifted to Universal Feeder items and the over-all rate gradually dropped, accelerating again in the final two sessions during which S employed the 10¢ tube.

No systematic rate differences between the two schedules can be detected on the daily session record. Fig. 9 shows that response rates for the components were essentially parallel, the VI curve beginning lower than VR until point A, then crossing and remaining above the VR curve until point B, at which point the VI rate declines slightly. Thus, differential responding was not controlled by the multiple schedule for this S.

Insert Fig. 9 about here

The rate decline during Sessions 24-28 may be attributed to S having developed a behavior incompatible with reading, i.e., removing marbles from the tubes and depositing them in the funnel. Thus, much of S's time was occupied with the self-administered reinforcement of both reading and non-reading behaviors. This continued until the tubes were empty.

Extensive prompting was required to maintain the chaining sequence from pretraining into the reading program; this prompting was gradually faded as behavior became more reliable. Anticipatory behavior was extremely weak for this S, only seven such responses occurring even in pretraining. Half of the anticipations to reading material were emitted in Sessions 3-9; most of the remainder occurred only after prompting by E, even though S sometimes declared his intention to say them ahead of E.

Only 1066 reading trials were presented during the experiment, the absence of anticipatory responding requiring the 10-second delay period on most trials. 3.56% of the total responses were anticipated, 2.81% correctly.

Discussion

Several general implications are indicated by the results. First, the principles and techniques of operant conditioning appear to be extendable to the study of significant complex human behaviors--specifically, to the acquisition of reading. The multiple schedule design proved valuable for the study of individual schedule effects and the results were generally what would be expected on the basis of previous work (e.g., Ferster and Skinner, 1957).

In each case where a CRF schedule was used as the comparison schedule the appropriate results occurred. When the opposed schedule was EXT the discrimination was

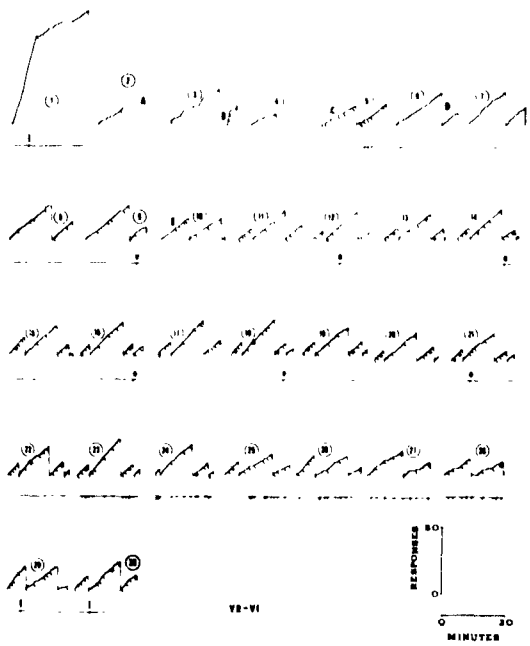


Fig. 8.--The daily session record for the subject presented a multiple variable ratio-variable interval reinforcement schedule.

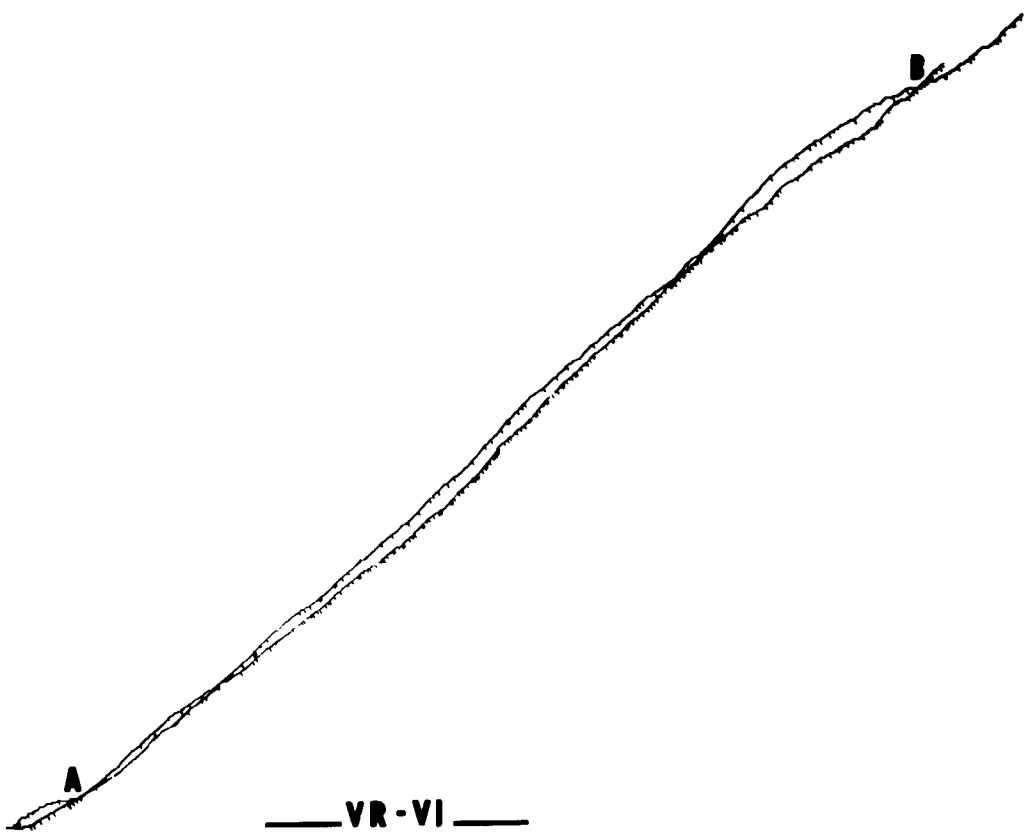


Fig. 9.--An over-all comparison of the data for the multiple variable ratio-variable interval reinforcement subject.

rapidly acquired and the greatest difference between component schedules of all subjects was evidenced. Under the CRF-VI schedule the VI component did not produce as high a rate of response as did the CRF. For the CRF-VR subject, on the other hand, the VR schedule produced a rate of response which was higher than that produced by the CRF.

Only the VR-VI schedule did not produce the expected results--and that appeared to be an artifact of the experimental procedure. That is, when an S did not anticipate there was a 10-second delay period for the trial. Thus, a subject who consistently failed to anticipate could only attain the rate limited by this delay procedure, which was the case with the VR-VI subject. Both components of this schedule appeared to maintain the subject's behavior at a maximum rate, within the limitation imposed by the lack of anticipation responses. This conclusion is supported by a comparison to a subject from a previous study who also did not anticipate (Staats, Minke, Finley, Wolf, and Brooks, in press). The subject in the present study averaged 42.4 responses per training session, whereas the subject in the previous study, under CRF conditions throughout, averaged 38.7 responses per session. Thus, it is quite possible that under a procedure where the rate is not limited by the 10-second delay, the expected differences between VR and VI schedules could be obtained, e.g., it would be possible for a VR schedule to result in a more rapid rate of response.

It is also of interest to note that this experiment included conditions which represent one of the few attempts to apply a VR schedule to human behavior. Sidman (1962) states that "Orlando and Bijou (1962) are the only investigators who have reported on this schedule and their work was with developmentally retarded children" (p. 184). Salzinger, et al (1962) have more recently reported an experiment in which speech rate in normal children was subjected to such a schedule.

Although there are improvements to be made in the procedure, and there are the qualifications already noted, the results of this study indicate that the general procedure and apparatus provide enough experimental control so that the dependent variable (acquisition of reading responses) is sensitive to the manipulation of important independent variables. This suggests that these developments may be extended to the study of a number of types of learning and to various special populations, e.g., deaf children, mutes, mental retardates, etc. Much operant research with humans has tended to involve only simple responses such as knob-pulling and button-pressing, and simple controlling stimuli; on the other hand, the present facility would seem to be useful in the study of the acquisition of complex responses of more immediate significance to human adjustment. This could also involve work which had remedial objectives.

As this discussion implies, in addition to studying the principles of general psychology in the context of this particular type of behavior, other goals of the project are the study of reading itself and the study of child learning in general. Thus, the project is interested in developing an experimental situation which maximizes behavior acquisition, a primary aspect of which is the development of the most efficacious reinforcement system. As has been noted by other investigators (e.g., Long, Hammack, May, and Campbell, 1958) it has been difficult to develop a reinforcer system which both maintains children's behavior well and is durable, i.e., does not weaken over time. The present reinforcement procedure appears to have solved this problem; however, a great deal of study remains in order to maximize the procedure. What is desired is a reinforcement system which will (1) produce

maximal rates, and (2) minimize the expenditure of reinforcers. The last stipulation involves both economy as well as the consideration that the fewer reinforcers given, the longer it will take the subject to satiate on the available reinforcers.

The experimental results which have so far emerged from the laboratory study of reading acquisition have implications for these problems. That is, a number of subjects have been run under various schedules, both single and multiple, and the results are interesting for their effects upon the average over-all rates of behavior produced per session, and for the cost in reinforcers in producing these rates. These effects can be seen by comparing the rates, reinforcers, and so on, of the multiple schedule subjects to each other as well as to the results of subjects run in the previous experiment which utilized strictly CRF conditions (Staats, Minke, Finley, Wolf, and Brooks, in press). These various results are shown in Table 1.

Insert Table 1 about here

As can be seen, the highest average rate per session was produced under CRF-EXT; the next highest, in order, were CRF-VR, CRF-VI, VR-VI, and then the CRF subjects. On the other hand, the VR-VI schedule involved the least expenditure of reinforcers. The CRF-VI and CRF-VR schedules involved about an equal frequency of reinforcement and yet the rates produced were higher for the latter, as would be expected. While the CRF-EXT schedule produced the highest average number of responses per session, the percentage of reinforcement for the responses was also high. Nevertheless, it is interesting to note that the highest CRF rate of any subject (including the straight CRF Ss) was produced when this schedule was paired with extinction, a finding which would be expected from Reynolds (1961a,b) study of the relationship of reinforcement frequency and behavioral contrast.

These data and the comparisons must be considered to be tentative since, as a consequence of the experimental procedure, rate was not independent of the number of anticipations the subject made. An anticipation, correct or incorrect, obviated the 10-second delay period. Thus, subjects who made many anticipations were afforded the opportunity of moving more rapidly. It is also true that any individual differences in rates were not controlled in these comparisons, since only one subject was run under each multiple schedule. Nevertheless, in broad outline, the results seem to contain some information. For example, the three CRF subjects appeared to produce rates which were highly similar. In addition, the results seem to indicate that the multiple schedules which involve intermittant reinforcement generally produced higher rates for less expenditure of reinforcers than did CRF--a very important finding in this situation for both practical and scientific purposes.

As Herrnstein and Brady (1958) point out, the effects of schedules upon behavior can be studied in a short time through the use of multiple schedules. However, there appears to be an interaction between the components of a multiple schedule (see also Reynolds, 1961a, 1961b). This is a limiting factor in generalizing the effects of a component in a multiple schedule to its effects in isolation. As a consequence there has been interest in studying the effects of interaction on the individual component. However, the effects of interaction upon the over-all rates produced under multiple schedules (as well as other types of combinations) have not yet been systematically studied. (See Herrick, Meyers, and Korotkin, 1959, for an indication that over-all rates of response under an S^D - S^Δ multiple schedule may be greater than under CRF).

Table 1

Subject	Sessions		Total Responses	Average Responses/ Session	Average Tokens/ Session	Average Responses/ Token	% Responses Reinforced	% Total Anticipations	% Correct Anticipations
	Whole Days on Reading	Total for Computations							
CRF # 1	4-11	8	294	36.7	36.7	1.00	100	76.4	40.5
CRF # 2	3-40	38	1473	38.7	38.7	1.00	100	2.3	2.1
CRF # 3	3-40	38	1305	34.5	34.5	1.00	100	47.4	45.3
CRF-EXT	4-30 less Session 23	26	1530	58.8	44.5	1.32	75.6	94.0	30.1
CRF-VR	5-30	26	1394	53.6	34.5	1.56	64.3	50.0*	46.9*
CRF-VI	4-30 less Sessions 17-19	24	1075	44.8	29.3	1.53	65.4	75.7**	25.0**
VR-VI	4-30 less Sessions 6-7	25	1060	42.4	11.4	3.72	26.9	3.6	2.8

* Session 26 omitted.
** Sessions 3-16 only.

Table 1.--Results of seven subjects run in this laboratory facility. Subjects CRF #1, #2, and #3 were employed in a procedure comparable to the present study, but were administered only continuous reinforcement conditions (see Staats, Minke, Finley, Wolf and Brooks, in press). Computations are based on full-length reading sessions; sessions omitted include pretraining phases, major deviations from normal procedure, or sessions for which complete data were unavailable.

The suggestion which has emerged from the laboratory study of reading acquisition so far is that multiple schedules can also have significance in terms of maximizing rates of response produced in the individual components and thus result in higher over-all rates. At the same time, multiple schedules may also offer the possibility of reducing the expenditure of reinforcers. Because of the import of such a finding for the study of human learning, where the reinforcer system may be a problem, the research project intends to systematically investigate the effects of multiple schedules (as well as other types of combinations) on over-all rates within the present experimental context.

References

Dulany, D. Awareness, consequence, and mediation in verbal conditioning. Mimeographed preprint, 1962.

Ferster, C. B. and Skinner, B. F. Schedules of reinforcement. New York: Appleton-Century-Crofts, 1957.

Herrick, R. M., Myers, J. L., and Korotkin, A. L. Changes in S^D and S^Δ rates during development of an operant discrimination. J. comp. physiol. Psychol., 1959, 52, 359-364.

Herrnstein, R. J., and Brady, J. V. Interaction among components of a multiple schedule. J. exp. anal. Behav., 1958, 1, 293-301

Long, E. R., Hammack, J. T., May, F., and Campbell, B. J. Intermittent reinforcement of operant behavior in children. J. exp. anal. Behav., 1958, 1, 315-339.

Orlando, R., and Bijou, S. W. Single and multiple schedules of reinforcement in developmentally retarded children. J. exp. anal. Behav., 1960, 3, 339-348.

Reynolds, G. S. An analysis of interactions in a multiple schedule. J. exp. anal. Behav., 1961a, 4, 107-117.

Reynolds, G. S. Relativity of response rate and reinforcement frequency in a multiple schedule. J. exp. anal. Behav., 1961b, 4, 179-184.

Salzinger, S., Salzinger, K., Portnoy, S., Eckman, J., Bacon, P. M., Deutsch, M., and Zubin, J. Operant conditioning of continuous speech in young children. Child Develpm., 1962, 33, 683-695.

Sidman, M. Operant techniques. In A. J. Bachrach (ed.), Experimental foundations of clinical psychology. New York: Basic Books, Inc., 1962.

Staats, A. W., Minke, K. A., Finley, J. R., Wolf, M. and Brooks, L. O. A reinforcer system and experimental procedure for the laboratory study of reading acquisition. Child Develpm., in press.

Staats, A. W., and Staats, C. K. A comparison of the development of speech and reading behavior with implications for research. Child Develpm., 1962, 33, 831-846.

Staats, A. W., Staats, C. K., Schutz, R. E., and Wolf, M. The conditioning of textual responses using "extrinsic" reinforcers. J. exp. anal. Behav., 1962, 5, 33-40.

Verplanck, W. S. Unaware of where's awareness: Some verbal operants--notates, moments and notants. In C. W. Eriksen (ed.), Behavior and awareness. Durham: Duke University Press, 1962.